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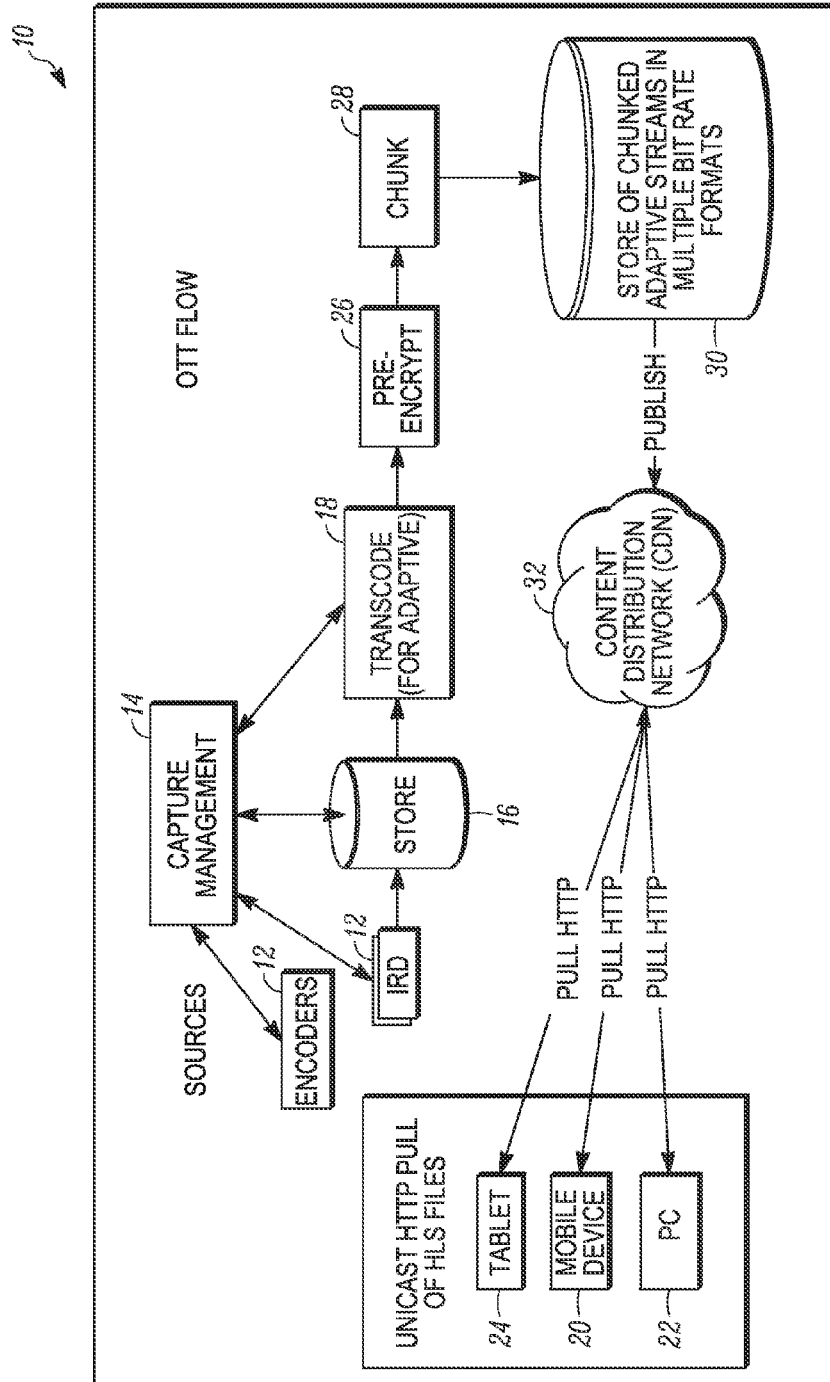


FIG. 1
(PRIOR ART)

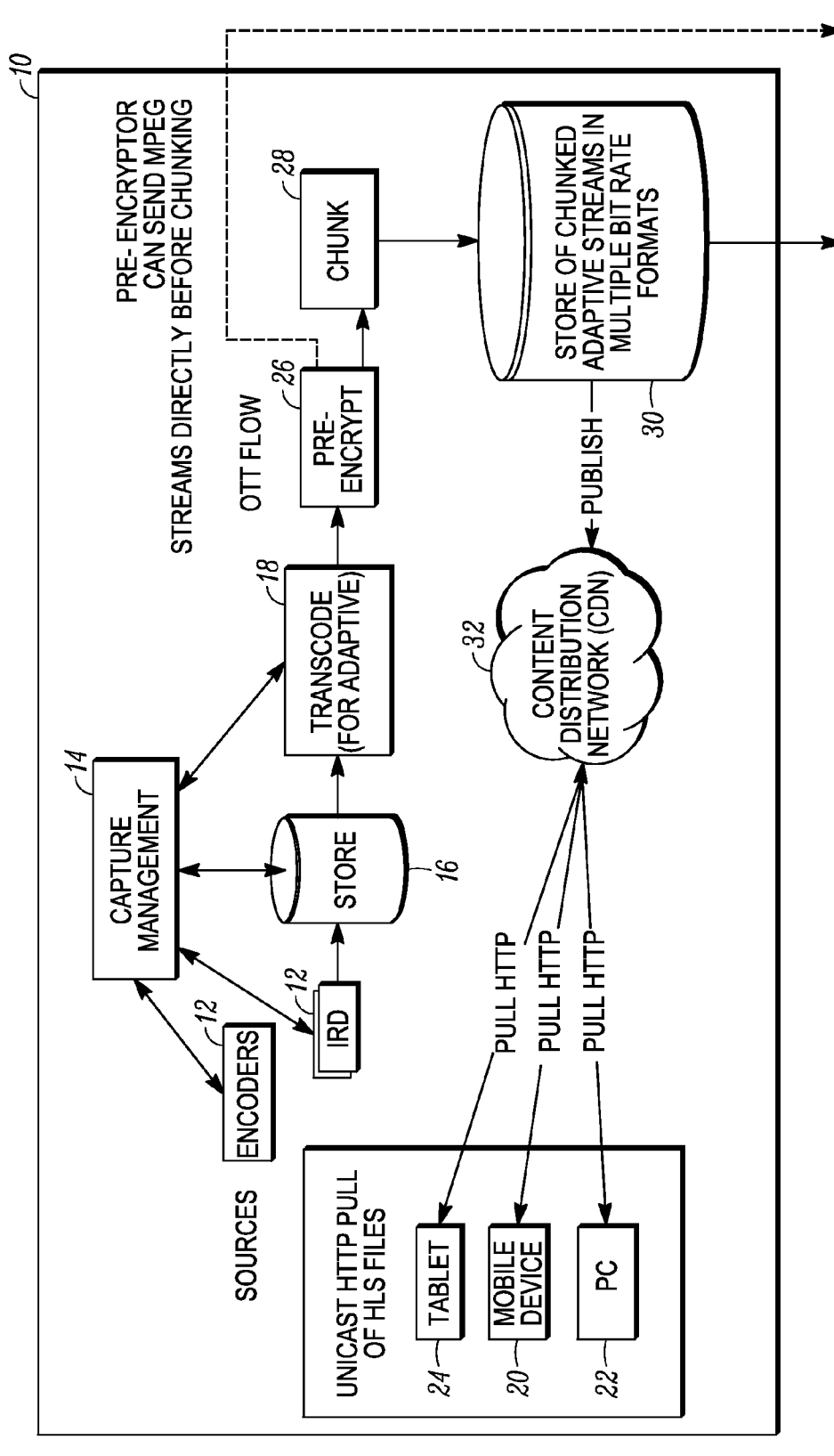


FIG. 2A

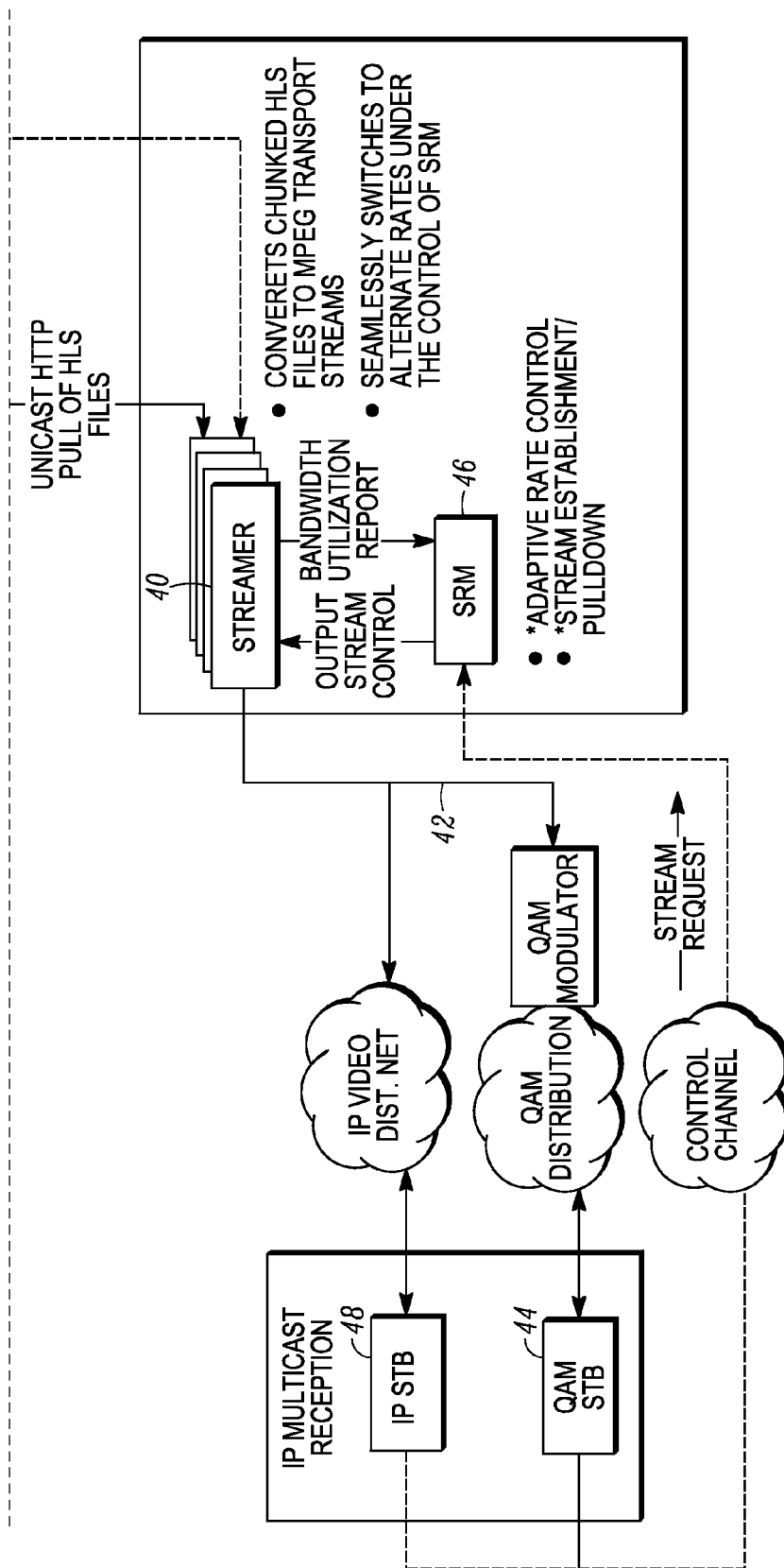


FIG. 2B

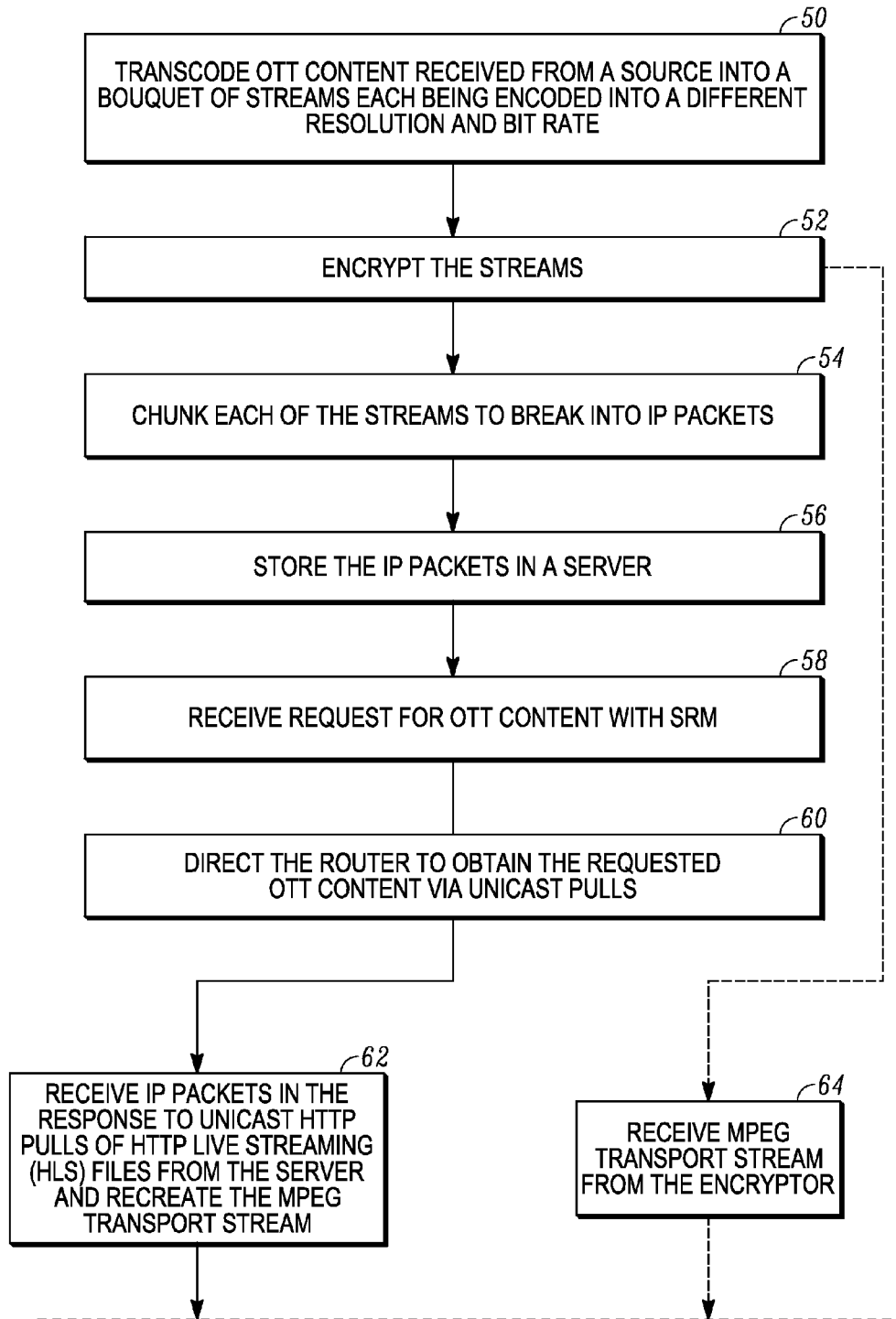


FIG. 3A

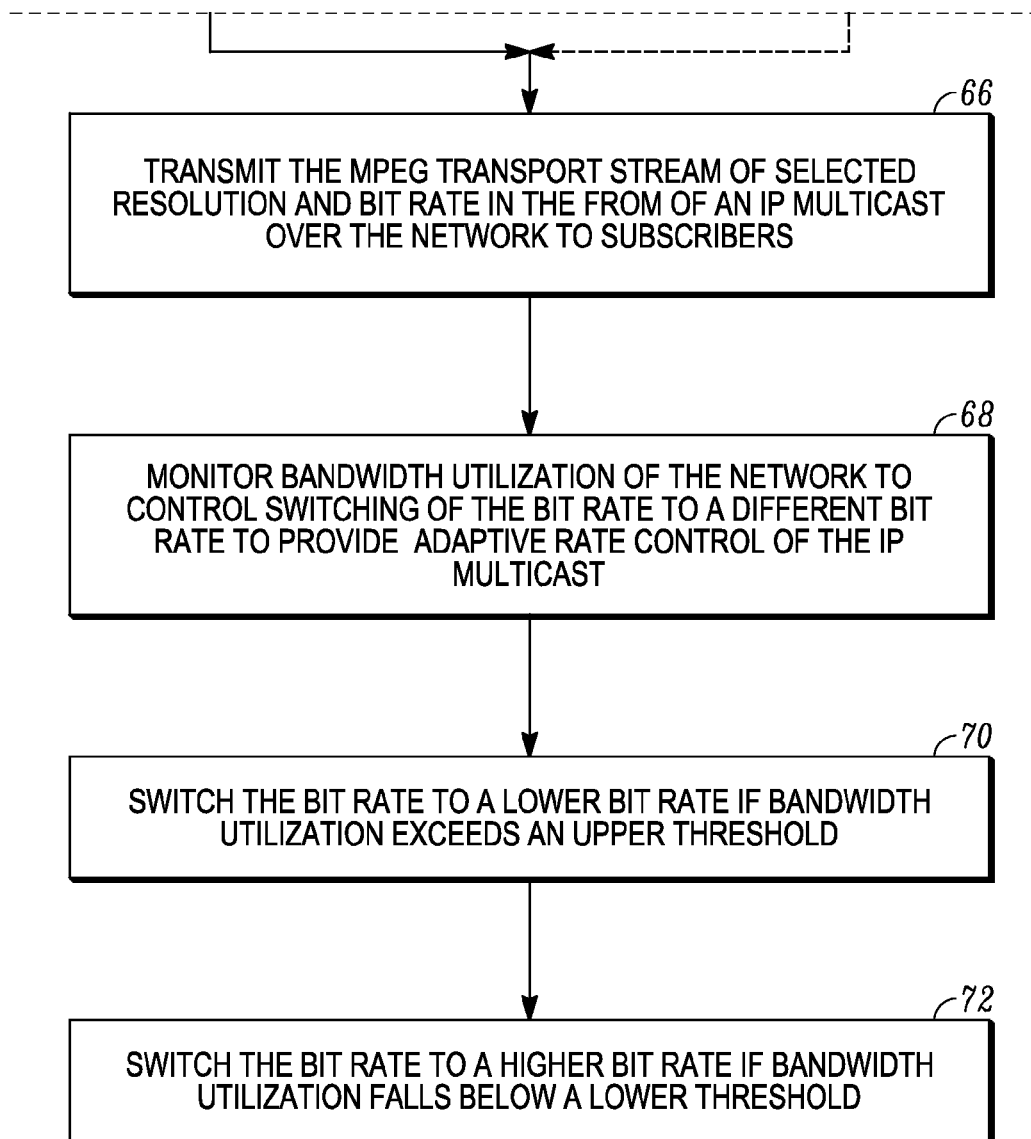


FIG. 3B

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METHOD AND APPARATUS FOR NETWORK BASED ADAPTIVE STREAMING

FIELD

Method and apparatus for streaming and distributing Over-the-Top (OTT) service and content to subscribers over a broadband network such as a multiple service operator (MSO) network are described.

BACKGROUND

Network operators typically distribute and deliver services and content over their network, such as cable television services over a cable network. In some cases, services and content of entities other than the network operator are distributed over the network operator's network resulting in increased utilization of the network operator's access network. This type of service and content is referred to as Over-the-Top (OTT) because the OTT service typically rides on top of the network operator's service yet may not be otherwise affiliated with the network operator or the network operator's services.

One example of an OTT service is Internet Protocol Television (IPTV) which refers to a service of providing video, audio and/or data content in the form of IP packets provided by a Service Provider over a closed network, such as a Data Over Cable (DOC) network. Thus, IPTV can be offered as an OTT service over an existing network of a network operator to customers connected to the network. In this manner, OTT provides the ability to offer linear broadcast television (TV) as a unicast IP service to subscribers both within and outside of a Service Provider's network. As used herein, the term "unicast" refers to a communication between a single sender and a single receiver over a network.

In addition, a service provider may create their own unicast based "adaptive or progressive" streaming service to distribute content to portable devices, such as tablets, computers, smart phones, and the like. Some of the subscribers to this particular service may be connected to another service provider's network while some subscribers may be connected to the service provider's access network. Thus, the service provider may distribute the same OTT services to portable devices within subscriber homes connected to the service provider's access network. In other words, OTT can be an adjunct service offering for subscribers on other service provider networks, and can also enhance the experience of on-network subscribers (e.g., by supporting their portable devices).

When additional OTT content is deployed on a network, such as a significant number of new High Definition (HD) services over an existing distribution network of a network operator, a result may be that the distribution network becomes capacity constrained due to bandwidth requirements needed to fulfill the OTT service. As an example, the QAM plant may be at or near capacity, and the IP distribution network may not be sized to carry all the HD services being planned, particularly, since the new OTT services require a unicast infrastructure. Further complicating the addition of OTT content is that it may be desired to deploy technology that can be leveraged to source these HD services to Set Top Boxes (STBs) or like Customer Premise Equipment (CPE) that have different IP capabilities (i.e., none to advanced) and to a variety of different mobile, PC, and tablet customer devices with varying IP capabilities (i.e., resolution, etc.) within the home or on wireless networks.

Simply by way of example, an existing IP video distribution network may not have sufficient capacity to deliver a

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desired 100 new HD services using a unicast OTT distribution method. For instance, assuming that the network's available capacity is uniformly distributed among all potential subscriber homes, there may be on average approximately 3.5 Mbps available for IPTV video services into each home. In this example, if 50% of the subscribers requested one of the new HD services (8 Mbps/service on average), the existing network would be oversubscribed.

The cost to add capacity to a distribution network is typically too exorbitant to consider as a solution to the above referenced problem. Accordingly, there exists a need for a method and apparatus that provide cost and bandwidth efficiencies to enable a capacity constrained network to effectively and efficiently promote the utilization of new content and services prepared for Over-the-Top (OTT) distribution to a population of subscribers, such as via legacy STBs or the like. Further, it may be desirable for such a method and apparatus to permit both next generation IPTV devices and legacy STBs to share a common video path infrastructure, even if the legacy network is capacity constrained.

SUMMARY

This disclosure describes a method of streaming Over-the-Top (OTT) content on a network to subscribers. A digital video transport stream of an item of the OTT content is obtained via unicast streaming and of a resolution and bit rate selected from an available set of different resolutions and bit rates for the digital video transport stream. The digital video transport stream of the selected resolution and bit rate is transmitted in the form of an IP multicast over the network to subscribers. Bandwidth utilization of the network is monitored so that switching of the bit rate to a different bit rate for the digital video transport stream can be controlled to provide adaptive rate control of the IP multicast.

This disclosure also describes apparatus for streaming Over-the-Top (OTT) content on a network to subscribers. The apparatus includes a streamer located at a headend of the network configured to obtain a Moving Pictures Experts Group (MPEG) transport stream of an item of the OTT content of a resolution and bit rate selected from a set of different resolutions and bit rates and to transmit the MPEG transport stream to subscribers in the form of an IP multicast over the network. The apparatus also includes a Session Resource Manager (SRM) located at the headend of the network for controlling the resolution and bit rate of the MPEG transport stream obtained and transmitted by the streamer to thereby enable adaptive rate control of the IP multicast.

BRIEF DESCRIPTION OF THE DRAWINGS

Various features of the embodiments described in the following detailed description can be more fully appreciated when considered with reference to the accompanying figures, wherein the same numbers refer to the same elements.

FIG. 1 is a schematic view of unicast OTT infrastructure and video stream processing flow in accordance with an embodiment.

FIGS. 2A and 2B are a schematic view of the OTT infrastructure and video stream processing flow of FIG. 1 in combination with an adaptive rate IP multicast system in accordance with another embodiment.

FIGS. 3A and 3B are a flowchart of process steps for delivering OTT content to customer devices in accordance with the embodiment shown in FIG. 2.

DETAILED DESCRIPTION

For simplicity and illustrative purposes, the principles of the embodiments are described by referring mainly to

examples thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the embodiments. It will be apparent however, to one of ordinary skill in the art, that the embodiments may be practiced without limitation to these specific details. In some instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the embodiments.

FIG. 1 illustrates a typical video processing path 10 involved in the creation and distribution of IPTV services based on OTT technology. Thus, FIG. 1 illustrates so-called unicast OTT infrastructure that typically exists for a broadband network such as a multiple service operator (MSO) network.

Source devices 12, such as IRDs, Encoders, or any other source of video/audio content, provide OTT content as MPEG packets within an IP datagram stream to the headend of the network. A Capture Management System 14 may store the content in a storage unit 16 for future processing and playout, or the content may be made available in substantially real-time or after a pre-determined time delay and be provided to a transcoder 18. For purposes of this disclosure, “real-time” includes a level of responsiveness that is sufficiently fast to keep up with the rate of processing the OTT content as well as a level of responsiveness that tolerates a degree of lateness or built-in delay.

The content passes through a transcoding process in the transcoder 18 whereby a single input stream is turned into a “bouquet” of streams, each encoded into a different resolution format and bit rate. The term “bouquet” as used herein refers to a collection of related streams, each constituting a unique bit rate and resolution pairing derived from the same original MPEG service. Typically, the original MPEG service is of the highest quality and may be referred to as a “golden copy”. For example, a 1080i/30 or 720p/60 resolution service at 19.2 Mbps may be the golden copy MPEG service that can be used to derive lower bit rate and quality versions of that service. The multiplicity of different stream formats and bit rates enables the OTT content to be sourced to devices with different capabilities, such as Smart Phone 20, personal computer 22, and tablet computer 24. In addition, the different bit rates support adaptive streaming, whereby the receiving client has the ability to measure network congestion and request a lower or higher bit rate stream from the source. This may eliminate visual impairments caused by network congestion (e.g. macro-blocking due to dropped packets, frozen frames) at the expense of higher resolution video.

After transcoding, the bouquet of streams is encrypted in an encryptor or pre-encryptor 26 and then chunked in a chunker 28. The chunking process breaks each stream into time slices (e.g. 10 second period) and places the stream of packets for that period into a standard file format container that includes the packets and metadata describing the content (e.g. .MP4 container). The files are placed on a server 30 that can publish them to a Content Distribution Network (CDN) 32 for smart distribution to the edges of the network (i.e., to Smart Phone 20, personal computer 22, tablet computer 24, and like customer devices or Customer Premise Equipment (CPE)).

Client devices 20, 22 and 24 pull the files from CDN 32 by using standard unicast HTTP Gets. An example of a typical adaptive streaming protocol is unicast HTTP Live Streaming (HLS). Other examples of adaptive streaming protocol include HTTP Dynamic Streaming (HDS) and IIS Smooth Streaming. The adaptive clients (such as HLS clients) continuously measure network performance and adaptively

request other file chunks containing higher or lower bit rate streams depending on the dynamic bandwidth that the network can support.

FIG. 2 illustrates an alternate or an additional system that provides cost and bandwidth efficiencies for delivering and processing OTT content on an otherwise capacity-constrained network. As described above, the part of the system encapsulated within the upper box represents the OTT content and existing infrastructure to be deployed. The remaining part of the system shown in FIG. 2 represents the portion of the system added to deliver additional OTT services, such as IPTV services to IP STBs 48 and QAM STBs 44 leveraging the existing OTT technology infrastructure.

The Streamer 40 pulls the HLS files stored on the CDN origin server (or other storage server) 30 and reconstructs a fully compliant MPEG transport stream from the files for transmission from the Streamer 40 via IP multicast. Because the Streamer 40 can pull HLS files from the origin server 30 and can translate them to a compliant MPEG transport stream, the existing OTT infrastructure is fully leveraged. As a contemplated option, the Streamer 40 can alternatively receive the MPEG transport streams (before chunking) directly from the Encryptor 26. In this case, the Streamer 40 would not have to reconstruct the transport streams from container files.

Because the network 42 for the legacy STBs 44 may be a bandwidth constrained network, that is also managed (QoS, bandwidth controlled), the use of IP multicast is more efficient from a capacity utilization point of view than using unicast HTTP. As an example, if an existing network supports roughly 6 Gbps of capacity, within the network, to support approximately 1800 homes for IP video distribution, and if 50% of the users attempted to pull one of 100 different HD channels to be offered over IP, then 900 STBs would be pulling a unique unicast stream from the CDN 32 over the network according to the arrangement described with respect to FIG. 1. If each stream is 8 Mbps, then the total required capacity is $900 \times 8 \text{ Mbps} = 7.2 \text{ Gbps}$. In this example, the network would be oversubscribed and would change bit rates of the unicast streams adaptively, which lowers quality. In contrast, if the multicast system described in FIG. 2 is used, even if all 100 Streams were being requested, the bandwidth required is $100 \times 8 \text{ Mbps} = 800 \text{ Mbps}$, or an order of magnitude less than that required for the system of FIG. 1. Accordingly, there is no need to change the bit rate in this example for the multicast system since it will be well below capacity thereby permitting high quality video to be maintained.

In FIG. 2, the Streamer 40 provides a control interface to the Session Resource Manager (SRM) 46. A group of Streamers 40 provides bandwidth utilization reports to the SRM 46 which has knowledge of the available bandwidth that has been allocated for video through the network 42. When the SRM 46 determines that the network 42 is approaching capacity, based on the set of Streamer utilization reports, the SRM 46 can take action based on policy rules configured on the device. For example, the SRM 46 can send control messages to a particular streamer or group of streamers 40 to pull a lower resolution/bit rate set of HLS files from those stored on the Origin server 30, or a lower bit rate stream from the encryptor 26. In this way, the SRM 46 and Streamer 40 provide network level adaptive bit rate control for a given service for the entire IP/QAM STB population, 44 and 48, served by that part of the network 42, rather than requiring each STB, 44 and 48, to have an adaptive client to request a lower resolution/bit rate set of files during times of network congestion. The lower bit rate stream is streamed on the same multicast not requiring the STB, 44 and 48, to join an alternate

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multicast. The STB, **44** and **48**, is only required to adapt to the lower bit rate gracefully. This may require the Streamer **40** to condition the stream appropriately to prevent glitches at the decoder.

The SRM **46** also receives stream requests from the client STBs, **44** and **48**, and switches a requested multicast stream onto the IP network **42** if the requested multicast stream is not already streaming. This is similar functionality offered by Switched Digital Video (SDV) Managers. By performing switched IP multicast and only placing content on the IP network **42** when required, additional bandwidth efficiencies can be realized in an IP multicast environment.

The arrangement described above for FIG. 2 allows a common OTT infrastructure to be deployed for the reception, transcoding, encryption, and storage of video services supporting all device types, including mobile **20**, PCs **22**, tablets **24**, legacy STBs **44** and IP STBs **48**. This system minimizes utilized bandwidth as linear broadcasts are offered via IP multicast versus HTTP unicast, allowing more efficient use of constrained IP network capacity. The system provides a policy based adaptive streaming capability at the network level so the benefits of adaptive streaming can be realized if the IP network is congested without the need to deploy adaptive clients in all legacy and IP STBs. The policy management algorithm can make dynamic decisions about the bandwidth available for ad content and can add more ad streams as the network utilization decreases (e.g. when more people join a particular multicast because of its popularity).

In addition, the above described technique permits a service provider/network operator to use the same infrastructure (equipment used to create the adaptive streams) to offer a “pseudo”—adaptive service to his IP STB population as well, in a very efficient manner. This is because adaptive multicast to such client devices is driven from the network and not the client (like in adaptive streaming). Essentially, the streamer **40** permits the service provider/network operator to tap into the OTT service infrastructure that the service provider/network operator put in place and can translate from unicast to multicast while enabling bandwidth management by the service provider/network operator instead of the user. Thus, this system allows a service provider/network operator to invest in OTT infrastructure (transcoders, packagers, encryptors, etc.) to source an OTT service to on and off network portable devices and, with a little more investment (streamer, SRM, etc.), the service provider/network operator can use the same infrastructure to source to IP STBs (and QAM STBs) with capacity management over a constrained IP/QAM network.

By way of example, a service provider/network operator can carve its access network up into managed and unmanaged “pipes”. Portable devices with adaptive clients can pull their respective unicasts. As the capacity of this part of the “pipe” or network becomes constrained, the clients could all adaptively move to lower and lower bit rates affecting the video quality. The managed “pipe” could source the adaptive multicast content to IP STBs or other devices capable of receiving a multicast. If this part of the network becomes constrained, the SRM could lower the offered bit rate within a give multicast based on policy. The effect is that the bandwidth of the network is better managed because the control is with the network SRM and distributed among many unicast clients. This puts control of network usage in the hands of the service provider/network operator for the part of the access network the service provider/network operator operates dedicated to managed devices.

By way of further explanation, FIG. 3 illustrates process steps for streaming Over-the-Top (OTT) content on a network to subscribers. As discussed with respect to FIG. 1, the pro-

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cess steps of the existing OTT infrastructure remain essentially the same. For instance, OTT content is received from a source and transcoded in step **50** into a bouquet of streams with each of the bouquet of streams encoded into a different resolution and bit rate to enable the OTT content to be sourced to customer devices of different IP capabilities and to support adaptive rate streaming. The bouquet of streams are then subject to encrypting in step **52** and chunking in step **54** such that each of the bouquet of streams is separated into a plurality of IP packets which can be stored in step **56** in the server **30** at the headend of the network.

The SRM **46** can receive a request in step **58** from a customer device, such as STB, **44** or **48**, for a particular item of the OTT content. The SRM **46** in step **60** then directs the streamer **40** to obtain and transmit the particular requested item of the OTT content over the network **42**. The streamer **40** obtains a digital video transport stream for the requested item of the OTT content of a resolution and bit rate selected from an available set of different resolutions and bit rates in one of the following ways. In step **62**, the streamer **40** receives IP packets of the requested item of OTT content in response to unicast HTTP pulls of HTTP Live Streaming (HLS) files from the server **30** and recreates a MPEG transport stream from the IP packets. As an alternative, in step **64**, the streamer **40** receives the digital video transport streams directly from the encryptor **26** (in a form before chunking of the OTT content). In step **66**, the digital video transport stream of a selected resolution and bit rate is transmitted across the network **42** to the STBs **44** and **48** in the form of an IP multicast.

In step **68**, the SRM monitors bandwidth utilization of the network **42** during the obtaining and transmitting steps and controls switching of the bit rate to a different bit rate for the digital video transport stream during the obtaining and transmitting steps to provide adaptive rate control of the IP multicast. For example, if bandwidth utilization on the network **42** monitored during the monitoring step **68** exceeds an upper pre-set bandwidth utilization threshold, the bit rate of the digital video transport stream will be switched to a lower bit rate. See step **70**. Alternatively, if bandwidth utilization on the network **42** falls below a lower pre-set bandwidth utilization threshold, the bit rate of the digital video transport stream will be switched to a higher bit rate, if possible. See step **72**. Steps **70** and **72** can be accomplished by switching the unicast HTTP pulls of the HLS files from the server **30** to HLS files of a higher or lower bit rate.

All of the above steps occur automatically as set by the network operator to ensure the efficient use of IP network capacity. This system provides a policy based adaptive streaming capability at the network level so the benefits of adaptive streaming can be realized if the IP network is congested without the need to deploy adaptive clients in all legacy and IP STBs.

The devices, units, modules, servers, streamers, routers, and storage discussed above can physically be provided on a circuit board or within an electronic device and can include various processors, microprocessors, controllers, chips, disk drives, and the like. It will be apparent to one of ordinary skill in the art that the modules, processors, controllers, units, and the like may be implemented as electronic components, software, hardware or a combination of hardware and software.

While the principles of the invention have been described above in connection with specific devices, systems, and methods, it is to be clearly understood that this description is made only by way of example and not as limitation on the scope of the invention as defined in the appended claims.

We claim:

1. A method of streaming Over-the-Top (OTT) content on a network to subscribers, comprising:

obtaining via unicast streaming a digital video transport stream of an item of the OTT content, the digital video transport stream being of a resolution and bit rate selected from an available set of different resolutions and bit rates for the digital video transport stream; transmitting the digital video transport stream of the selected resolution and bit rate in an Internet Protocol (IP) multicast stream over the network to subscribers; monitoring bandwidth utilization of the network during the obtaining and transmitting operations to control switching of the bit rate to a different bit rate for the digital video transport stream during the obtaining and transmitting operations to provide adaptive rate control of the IP multicast stream by retrieving the digital video transport stream via the unicast streaming at the different bit rate,

wherein unicast pulls associated with the unicast streaming of the digital video transport stream from a server at a headend of the network are switched to a streaming file of a higher bit rate when the monitored bandwidth utilization of the network is below a lower bandwidth utilization threshold and the unicast pulls are switched to another streaming file of a lower bit rate when the monitored bandwidth utilization of the network exceeds an upper bandwidth utilization threshold.

2. The method according to claim 1, further comprising:

transcoding the OTT content received from a source into a bouquet of streams, each of the bouquet of streams encoded into a different resolution and bit rate to thereby permit the OTT content to be sourced to customer devices of different IP capabilities and to thereby support adaptive rate streaming;

encrypting, after the transcoding operation, the bouquet of streams with an encryptor;

chunking, after the encrypting operation, each of the bouquet of streams to break each of the bouquet of streams into a plurality of IP packets; and

storing the IP packets in a server at a headend of the network.

3. The method according to claim 2, wherein the obtaining operation includes:

receiving IP packets of the item of the OTT content in response to unicast Hypertext Transfer Protocol (HTTP) pulls of HTTP Live Streaming (HLS) files from the server at the headend of the network; and recreating the digital video transport stream from the IP packets.

4. The method according to claim 2, wherein the obtaining operation includes receiving digital video transport streams directly from the encryptor at the headend of the network.

5. The method according to claim 1, wherein a Session Resource Manager (SRM) located at a headend of the network automatically performs the controlling operation.

6. The method according to claim 5, wherein a streamer located at the headend of the network automatically performs the obtaining and transmitting operations.

7. The method according to claim 6, further comprising receiving with the SRM a request from a customer device for a particular item of the OTT content and thereafter performing the obtaining and transmitting operations with the streamer for the particular item of the OTT content.

8. The method according to claim 1, wherein the digital video transport stream is a Moving Pictures Experts Group (MPEG) transport stream.

9. An apparatus for streaming Over-the-Top (OTT) content on a network to subscribers, comprising:

a streamer located at a headend of the network to obtain a Moving Pictures Experts Group (MPEG) transport stream of an item of the OTT content of a resolution and bit rate selected from a set of different resolutions and bit rates via unicast streaming and to transmit the MPEG transport stream to subscribers in an Internet Protocol (IP) multicast stream over the network; and

a Session Resource Manager (SRM) located at the headend of the network for monitoring bandwidth utilization of the network and for controlling the resolution and bit rate of the MPEG transport stream obtained and transmitted by the streamer to enable adaptive rate control of the IP multicast stream by obtaining the item of the OTT content at different resolutions and bitrates via the unicast streaming, wherein unicast pulls associated with the unicast streaming of the MPEG transport stream from the headend of the network are switched to a streaming file of a higher bit rate when the monitored bandwidth utilization of the network is below a lower bandwidth utilization threshold and the unicast pulls are switched to another streaming file of a lower bit rate when the monitored bandwidth utilization of the network exceeds an upper bandwidth utilization threshold.

10. The apparatus according to claim 9, wherein the streamer is configured to obtain the MPEG transport stream by obtaining Internet Protocol (IP) packets of the item of the OTT content by unicast Hypertext Transfer Protocol (HTTP) pulls of HTTP Live Streaming (HLS) files from a server at the headend of the network and by recreating the MPEG transport stream from the IP packets.

11. The apparatus according to claim 9, further comprising:

a transcoder for transcoding the OTT content into a bouquet of streams, each of the bouquet of streams encoded into a different resolution and bit rate to thereby permit the OTT content to be sourced to customer devices of different IP capabilities and to support adaptive rate streaming;

an encryptor for encrypting the bouquet of streams;

a chunker for breaking each of the bouquet of streams into a plurality of IP packets; and

a server for storing the IP packets at the headend of the network.

12. The apparatus according to claim 11, wherein the streamer is configured to obtain the MPEG transport stream from the encryptor.

13. The apparatus according to claim 9, wherein the SRM is configured to receive requests for items of the OTT content from customer devices and thereafter direct the streamer to obtain and transmit requested items of the OTT content over the network at a resolution based on capabilities of the customer device.

14. A non-transitory computer readable medium comprising instructions that, when executed by a processor, cause the processor to perform operations comprising:

obtaining via unicast streaming a digital video transport stream of an item of Over-the-Top (OTT) content, the digital video transport stream being of a resolution and bit rate selected from an available set of different resolutions and bit rates for the digital video transport stream;

transmitting the digital video transport stream of the selected resolution and bit rate in an Internet Protocol (IP) multicast stream over a network to subscribers;

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monitoring bandwidth utilization of the network during the obtaining and transmitting operations to control switching of the bit rate to a different bit rate for the digital video transport stream during the obtaining and transmitting operations to provide adaptive rate control of the IP multicast stream by retrieving the digital video transport stream via the unicast streaming at the different bit rate,

wherein unicast pulls associated with the unicast streaming of the digital video transport stream from a server at a headend of the network are switched to a streaming file of a higher bit rate when the monitored bandwidth utilization of the network is below a lower bandwidth utilization threshold and the unicast pulls are switched to another streaming file of a lower bit rate when the monitored bandwidth utilization of the network exceeds an upper bandwidth utilization threshold.

15. The non-transitory computer readable medium according to claim **14**, the operations further comprising: transcoding the OTT content received from a source into a bouquet of streams, each of the bouquet of streams

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encoded into a different resolution and bit rate to thereby permit the OTT content to be sourced to customer devices of different IP capabilities and to thereby support adaptive rate streaming;

encrypting, after the transcoding operation, the bouquet of streams with an encryptor;

chunking, after the encrypting operation, each of the bouquet of streams to break each of the bouquet of streams into a plurality of IP packets; and

storing the IP packets in a server at a headend of the network.

16. The non-transitory computer readable medium to claim **15**, wherein the obtaining operation includes:

receiving IP packets of the item of the OTT content in response to unicast Hypertext Transfer Protocol (HTTP) pulls of HTTP Live Streaming (HLS) files from the server at the headend of the network; and

recreating the digital video transport stream from the IP packets.

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